# Regularization of 2D seismic data by using the CRS stacking operator: Application in real low-fold land data

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## Abstract

Regularization of seismic prestack data is an important step for time or depth domain prestack migration and also for velocity analysis. For several factors the seismic data may be acquired in sparse and irregular spatial positions. Usually, regularization algorithms produce output data in a regular spatial position by means of interpolation the irregular sampled input data. For this task, we present a regularization algorithm based on the CRS (common-reflection-surface) method. We show the application of this regularization algorithm in noisy and low fold land seismic data and as a result it produces prestack data gathers with improved signal-to-noise ratio and enhanced coherent seismic events. In this work, we use the regularized data in prestack time migration.

## Introduction

Due to several factors the seismic data acquisition is performed in a sparse and irregular sampling grid in space. This poorly sampled seismic data may create aliasing artifacts in the prestack migration and produce low quality results, mainly in land data with low irregular fold and noisy. To overcome these problems the prestack data must be regularized and interpolated previously to the migration process. There are several approaches for prestack data interpolation and regularization such as those using the Fourier theory, others based on azimuth moveout (AMO) and others that use sophisticated interpolation techniques. The output of the regularization algorithms are prestack data positioned in a regular grid and with regular fold, convenient for subsequent processes such as the velocity analysis, imaging and inversion processes.

The CRS stack method was introduced to simulate ZO stacked data from multi-coverage dataset (Müller, 1998; Jäger at al., 2001). Once the CRS attributes are known, they can be useful for several applications, such as the determination of the velocity model (Duveneck, 2004), AVO analysis (Pruessman et al., 2004), prestack data enhancement (Baykulov and Gajewski, 2009), Kirchhoff type pre-stack depth migration (Garabito et al., 2012) and time migration (Garabito, 2014) and others.

Following the approach introduced in Baykulov and Gajewski (2009), in this work we present a new algorithm for prestack data regularization and interpolation based on the CRS stack method. That is, the CRS attributes and the CRS stacking operator are used for prestack data interpolation and reconstruction generating an output data for a regular grid positions. This regularization improves the signal-to-noise ratio of the seismic data by attenuating the random noise and enhancing the coherent seismic events. We apply the proposed regularization algorithm to real land data with low fold and noisy, acquired in the Tacutu Basin, northern of Brazil. The regulation is applied in the common-offset domain and taking into account the topography variations. The regularized data was submitted to the conventional prestack time migration and the result is compared with the migrated image resulting from the original data.

## Regularization

The CRS stacking operator is a second-order hyperbolic traveltime approximation defined in midpoint-offset coordinates and it is dependent on three kinematic wavefiled attributes, so-called CRS-attributes. In the CRS stack method, for each sample point of the ZO section, these three attributes are determined from the prestack data by using optimization strategies based on coherence measure of the seismic signal. In Jagër et al., (2001) the CRS-attributes are determined in several steps using the CRS operator reduced for the common-midpoint (CMP) and zero-offset (ZO) configurations. In Garabito et al., (2012) the CRS-attributes are determined simultaneously using a multidimensional global optimization algorithm.

For successful applications the CRS-attributes need to be determined with good accuracy. Usually, the use of the one-step global optimization strategy produces more accurate CRS-attributes than multi-step strategies, mainly in low quality, low fold and noisy data. So, in this work, to determine the CRS-attributes we use the global optimization strategy proposed in Garabito et. al., (2012).

The CRS operator can be simplified or reduced for different seismic data configurations, namely, common-shot (CS), common-receiver (CR), common-midpoint (CMP) and common-offset (CO). Then, knowing the CRS attributes we can use the CRS operator to perform partial stacks in any of these seismic configurations, and as a result we can obtain a regularized data. In this work the regularization is performed in the CO configuration, that is, we generate regularized CO gathers for a predefined number of offsets.

Although a specific configuration is chosen for regularization, the reconstructed or interpolated trace is obtained from stacking of the traces corresponding to certain aperture, i.e., traces with offsets and midpoints near to the reference trace. The main steps for the regularization algorithm proposed in this work are: 1) preprocessing the prestack data, 2) determination of the CRS-attributes, 3) definition of the regularization output grid, 4) local stacking using the CRS staking operator, 5) put the source and receiver static values to the regularized trace.

The proposed regularization algorithm is performed considering the topography variations, therefore, when it is applied to land data there is need to calculate the static values for the regularized or interpolated traces.

**Application example**

We apply the regularization algorithm to the seismic line 50-RL-87 of Tacutu Basin, located in the northern part of Brazil. This seismic line was acquired in 1980 and is composed of ??? common-shot gathers with 200 m spacing, each shot with 96 traces with 50 m spacing distributed in a split-spread arrangement. This old seismic data is very noisy, sparse and with a low fold (12 traces), which may compromise all processing steps and the quality of final results.

This dataset was submitted to the conventional processing steps starting from the geometry, edition, calculation of static correction, F-K filtering, deconvolution, etc., until the residual static correction. In Figure 1 is shown a CMP gathers resulting from the conventional processing. This processed data is the input for prestack time migration and for the CRS processing. By means of global optimization strategy proposed in Garabito et. al., (2012) we obtain the CRS-attributes, after we apply the regularization algorithm to produce the reconstructed prestack data. In Figure 2 is presented the result of regularization for the same CMP gathers shown in Figure 1. The regularized CMP gathers show twice traces that the original CMP gather, that is, the new prestack data has a regular fold with 24 traces. In this case the preexistent traces were reconstructed and new traces were generated by interpolation. In the regularized CMP gather the noise was drastically attenuated and the reflection events are more clearly visible.

In the original data and regularized data were applied the Kirchhoff prestack time migration. In Figure 3 is the migrated image of the original data and in Figure 4 is the result of the regularized data. The quality of the migrated image was improved and the signal-to-noise was increased. In right side the fault is better define and the reflection events were better defined in all section.

**Conclusions**

We present a new regularization algorithm based on the CRS stack method. The regularization and interpolation is performed considering the topography variation, which is important for real land data. The application on real land data with low fold and low signal-to-noise ratio shows a great improvement in quality of the reconstructed

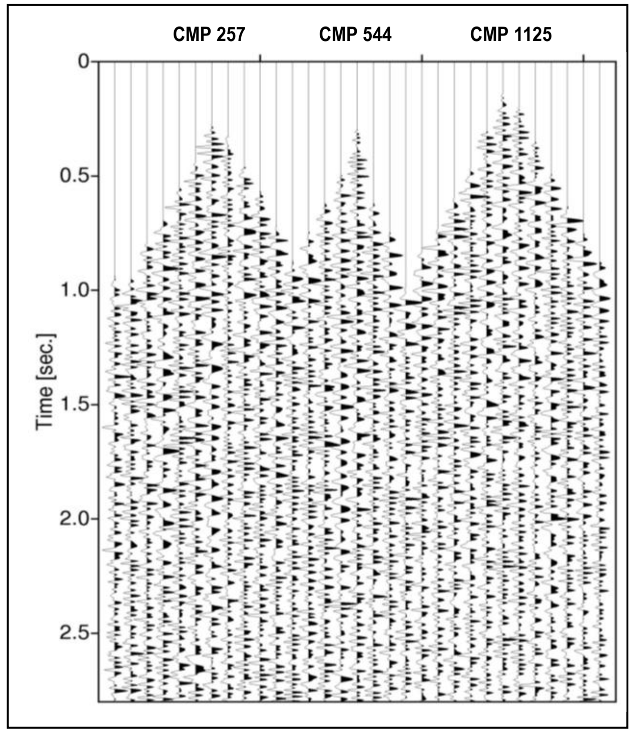


Figure 1 – Three non-regularized CMP gathers extracted from different locations on the seismic line. The maximum fold of the data is 12 traces.

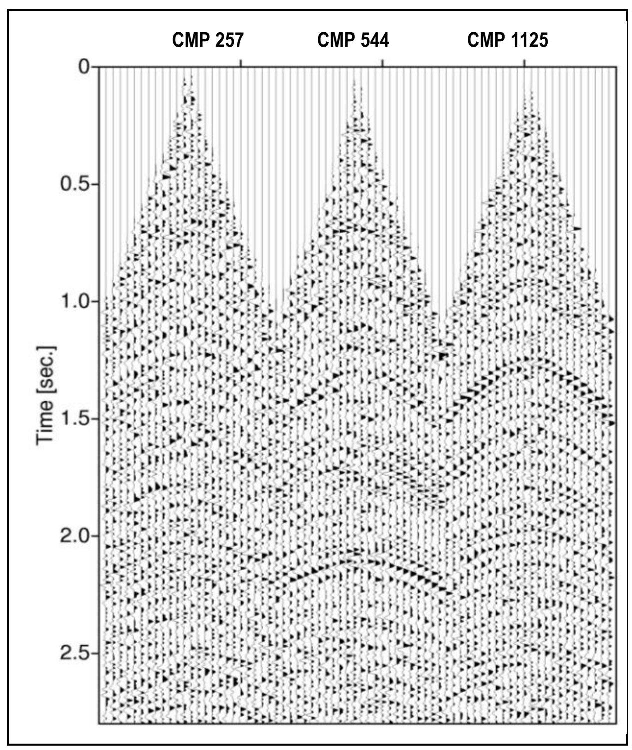


Figure 2 – Regularized CMP gathers corresponding to the same CMPs shown in Figure 1. The fold was incremented to 24 traces per CMP.

prestack data and also in the prestack migrated image. In this work we show only the application of the regularized data in time imaging, but most important applications are in the velocity analysis process for depth velocity model construction and prestack depth migration. These applications will be shown in future works.

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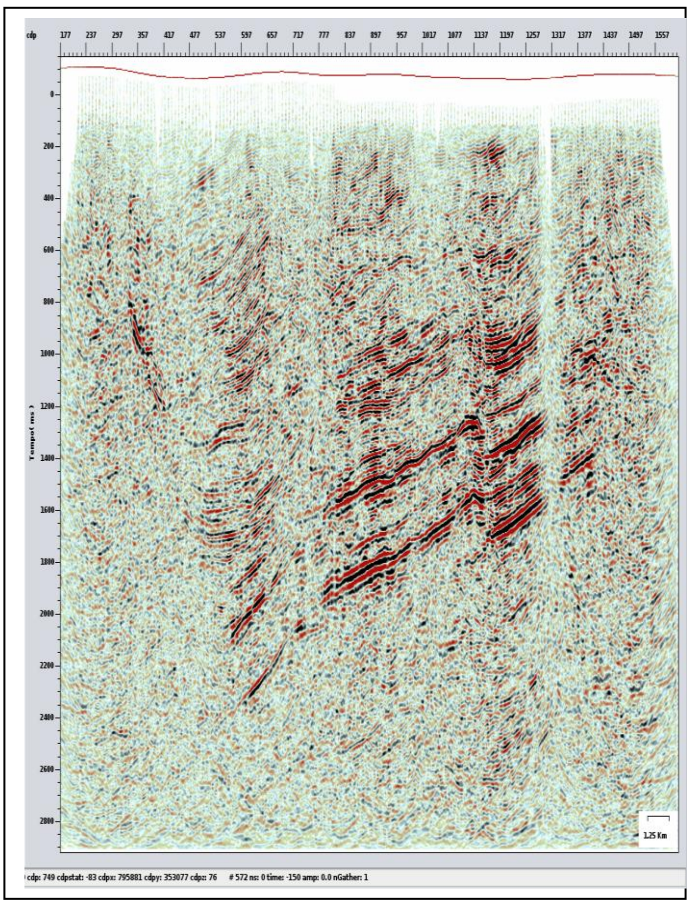


Figure 3 – Kirchhoff PSTM section resulting from the non-regularized data. The continuity of the reflection events is poor mainly in the upper and right regions.

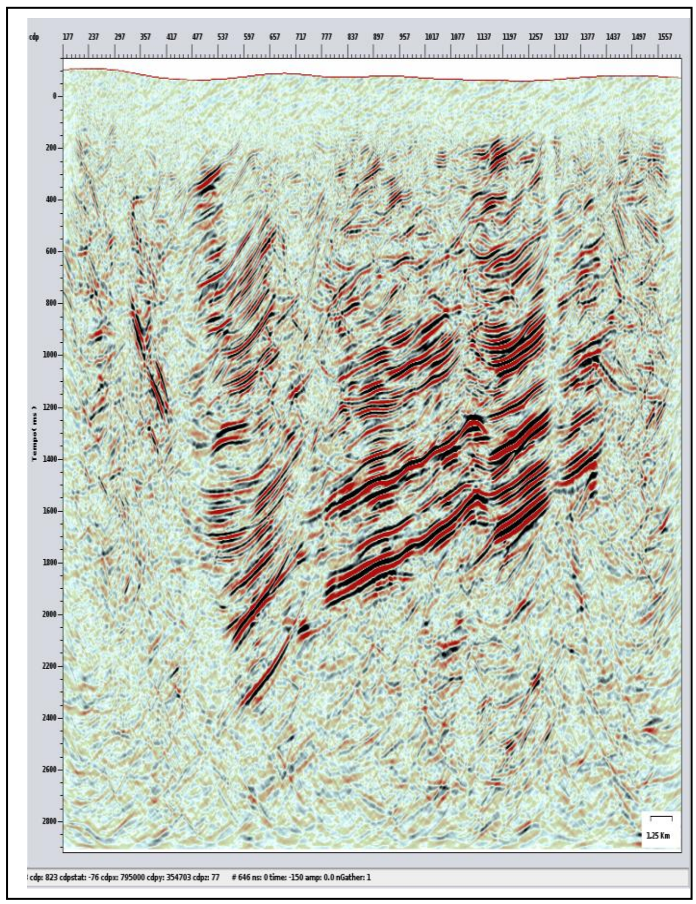


Figure 4 – Kirchhoff PSTM section resulting from the regularized data. The image quality was improved significantly compared with the conventional result.